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(54) **COMPUTER SYSTEM FOR DISTRIBUTED DISCOVERY OF VULNERABILITIES IN APPLICATIONS**

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See application file for complete search history.

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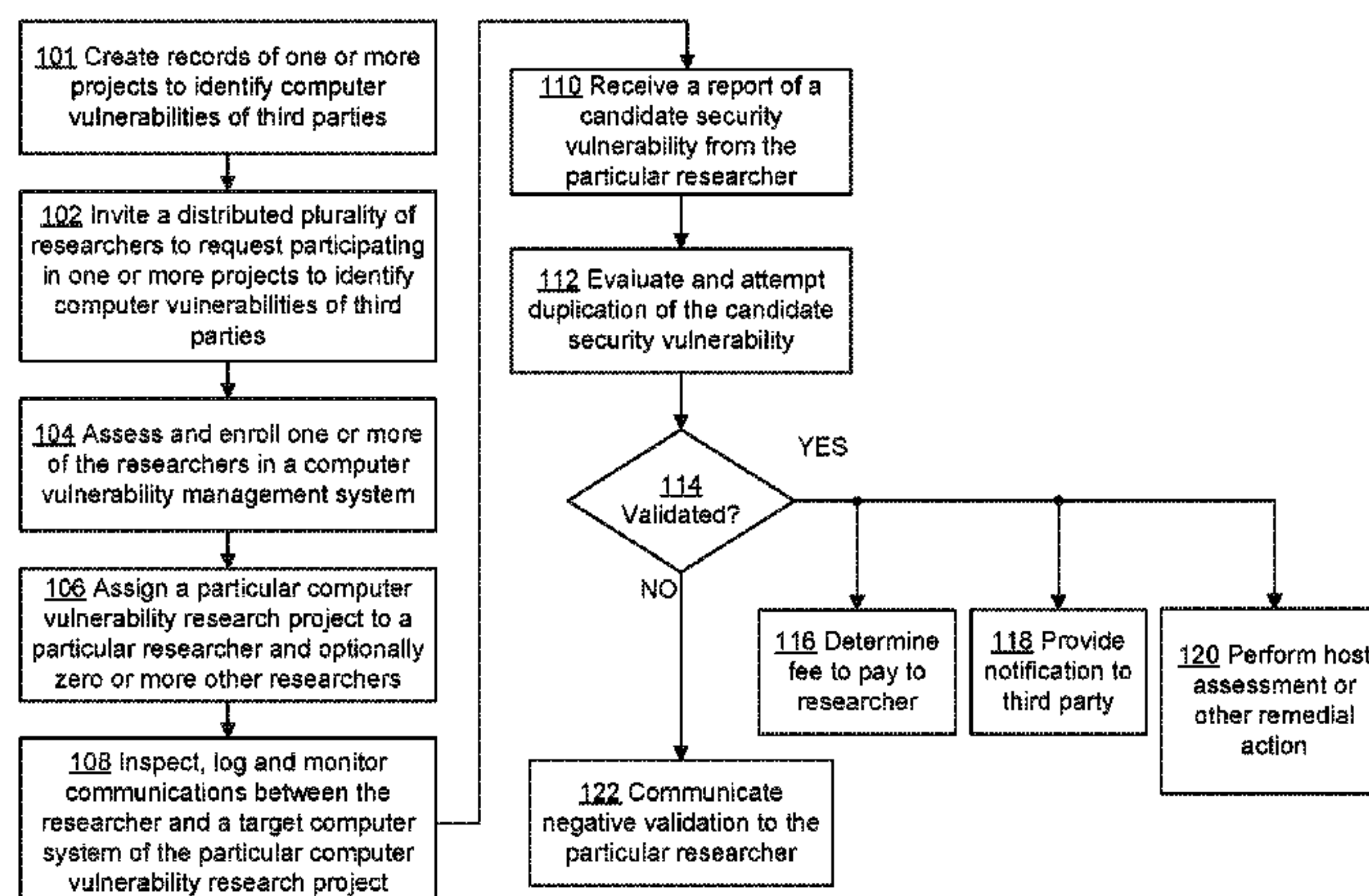
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(57) **ABSTRACT**

In one aspect, the disclosure provides: A method comprising: inviting a distributed plurality of researchers to participate in one or more computer vulnerability research projects directed to identifying computer vulnerabilities of one or more networks and/or computers that are owned or operated by a third party; assessing reputation and skills of one or more of the researchers, and accepting a subset of the researchers who have a positive reputation and sufficient skills to perform the investigations of the computer vulnerabilities; assigning a particular computer vulnerability research project, relating to a particular network under test, to a particular researcher from among the subset of the researchers; using a computer that is logically interposed between the particular researcher and the particular network under test, monitoring communications between the particular researcher and the particular network under test, wherein the communications relate to attempting to identify a candidate security vulnerability of the particular network under test; validating a report of the candidate security vulnerability of the particular network under test that is received from the particular researcher; determining and providing an award to the particular researcher in response to successfully validating the report of the candidate security vulnerability of the particular network under test that is received from the particular researcher.

**26 Claims, 6 Drawing Sheets**



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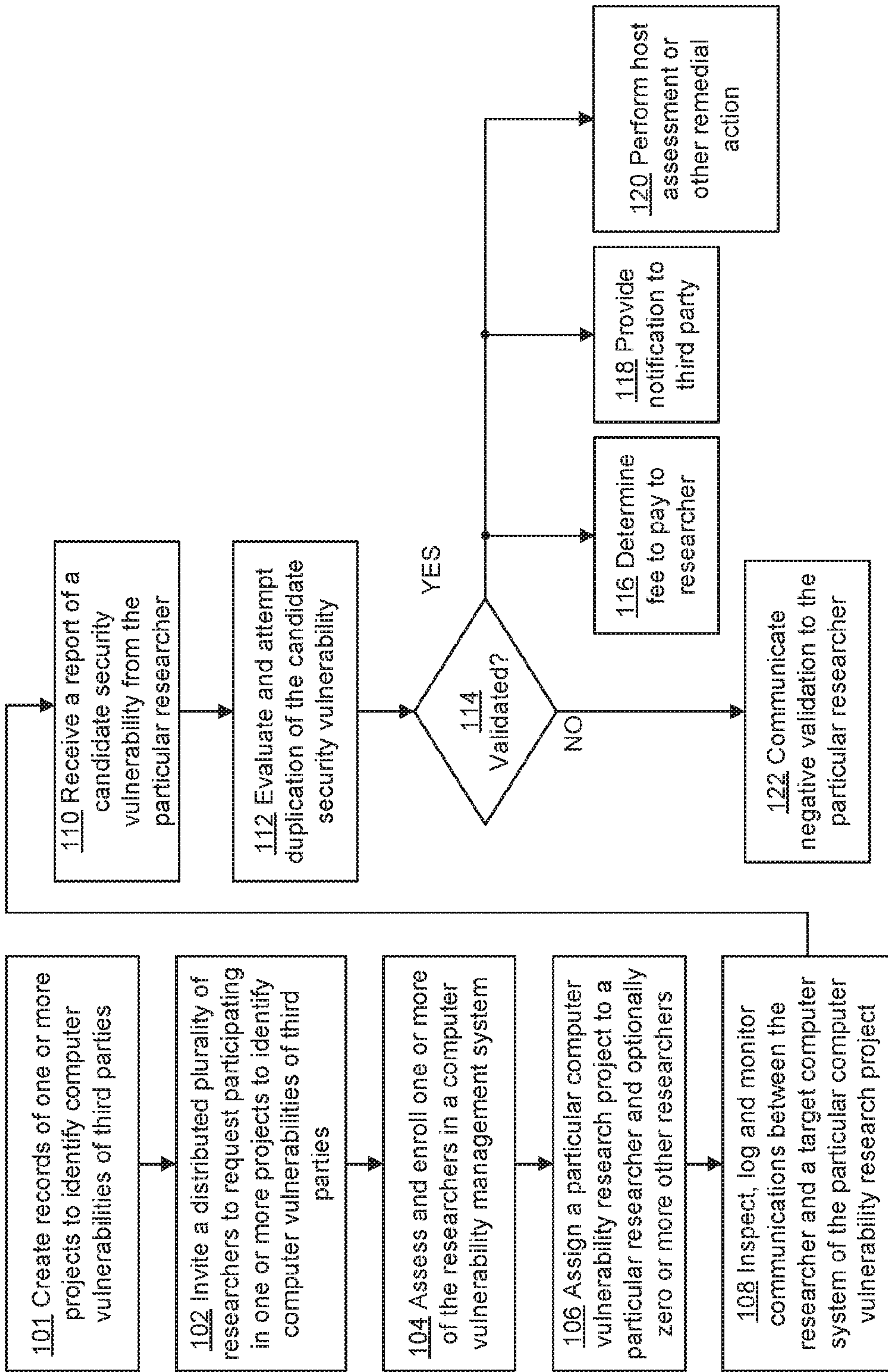


FIG. 1

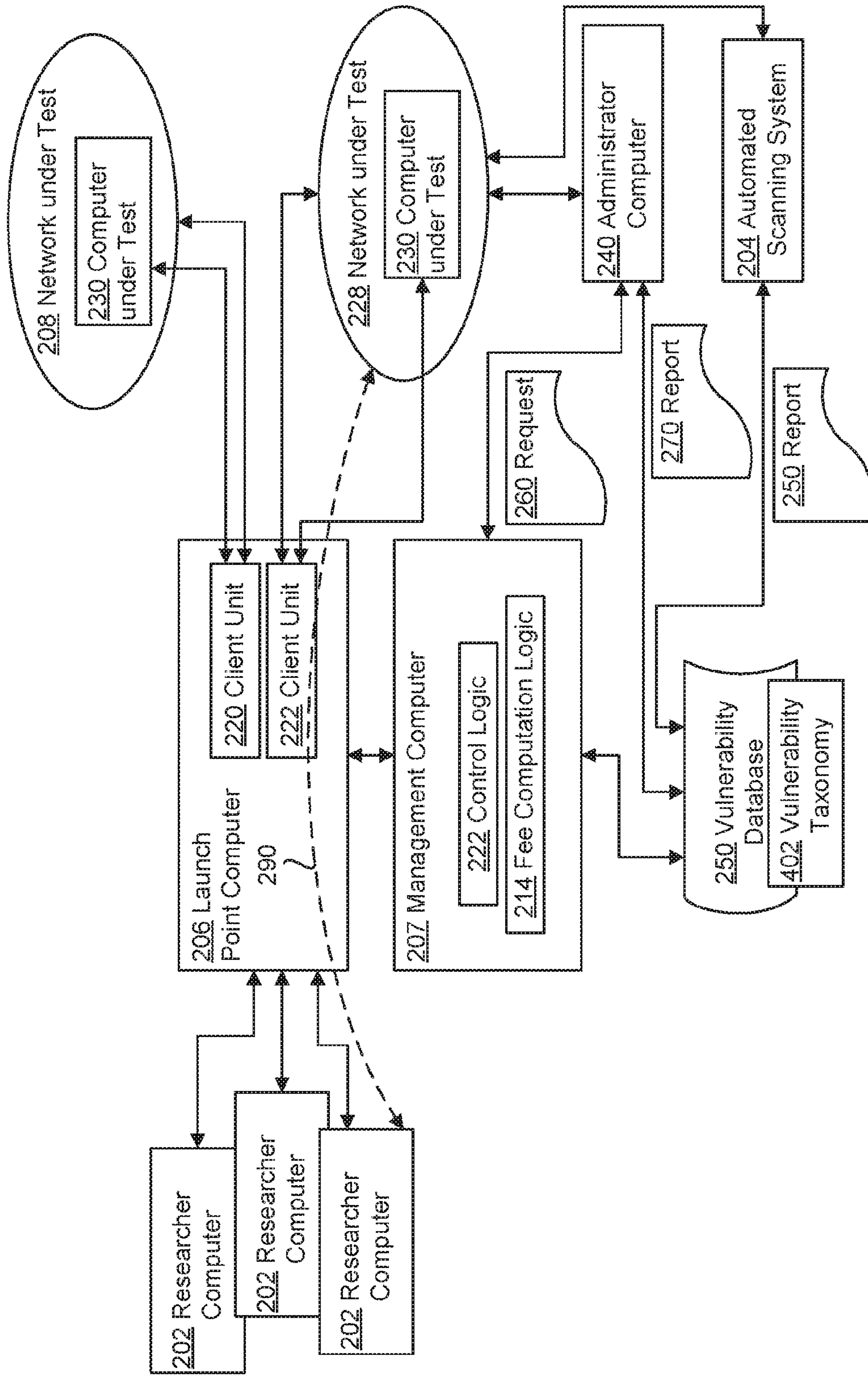


FIG. 2

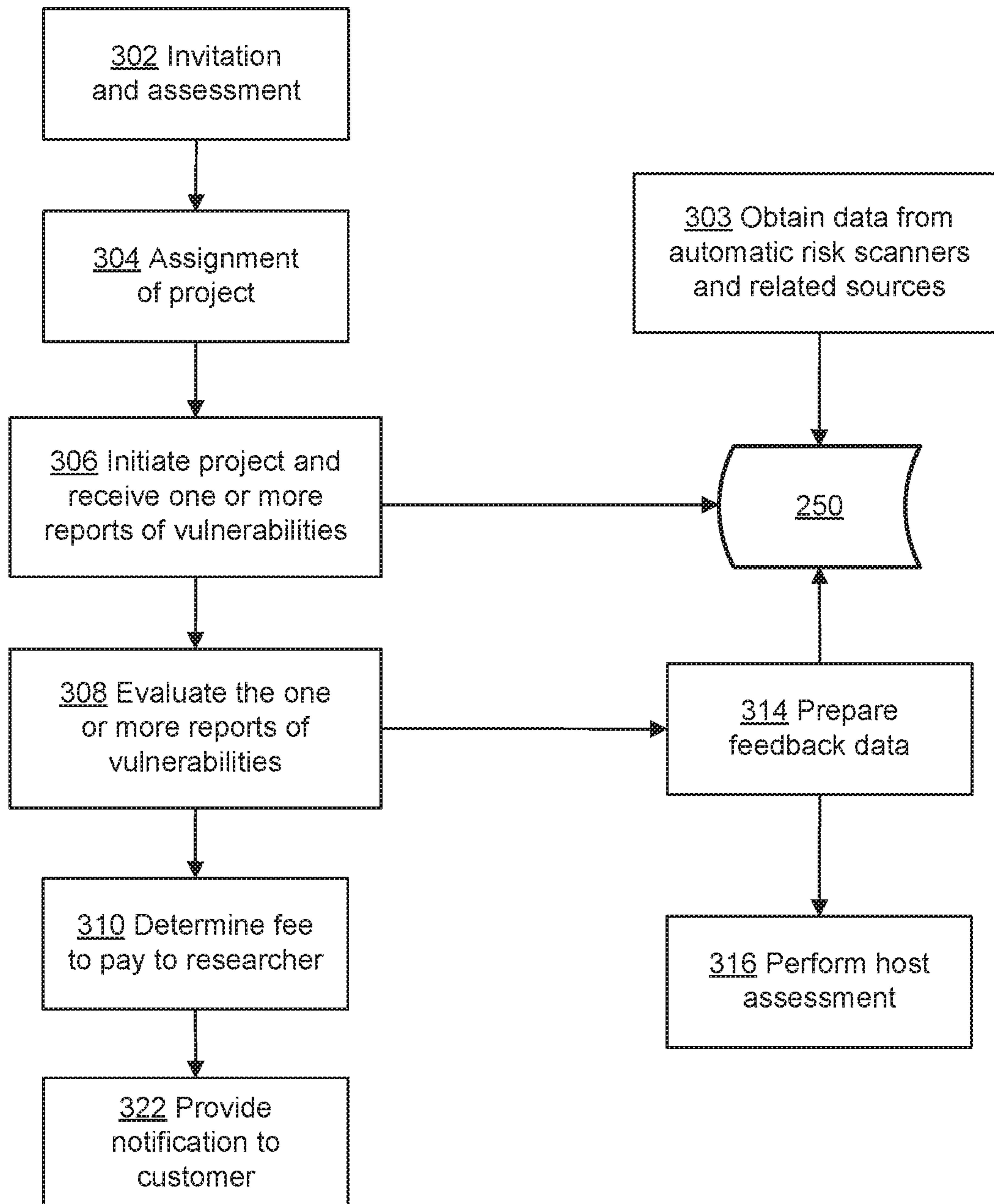
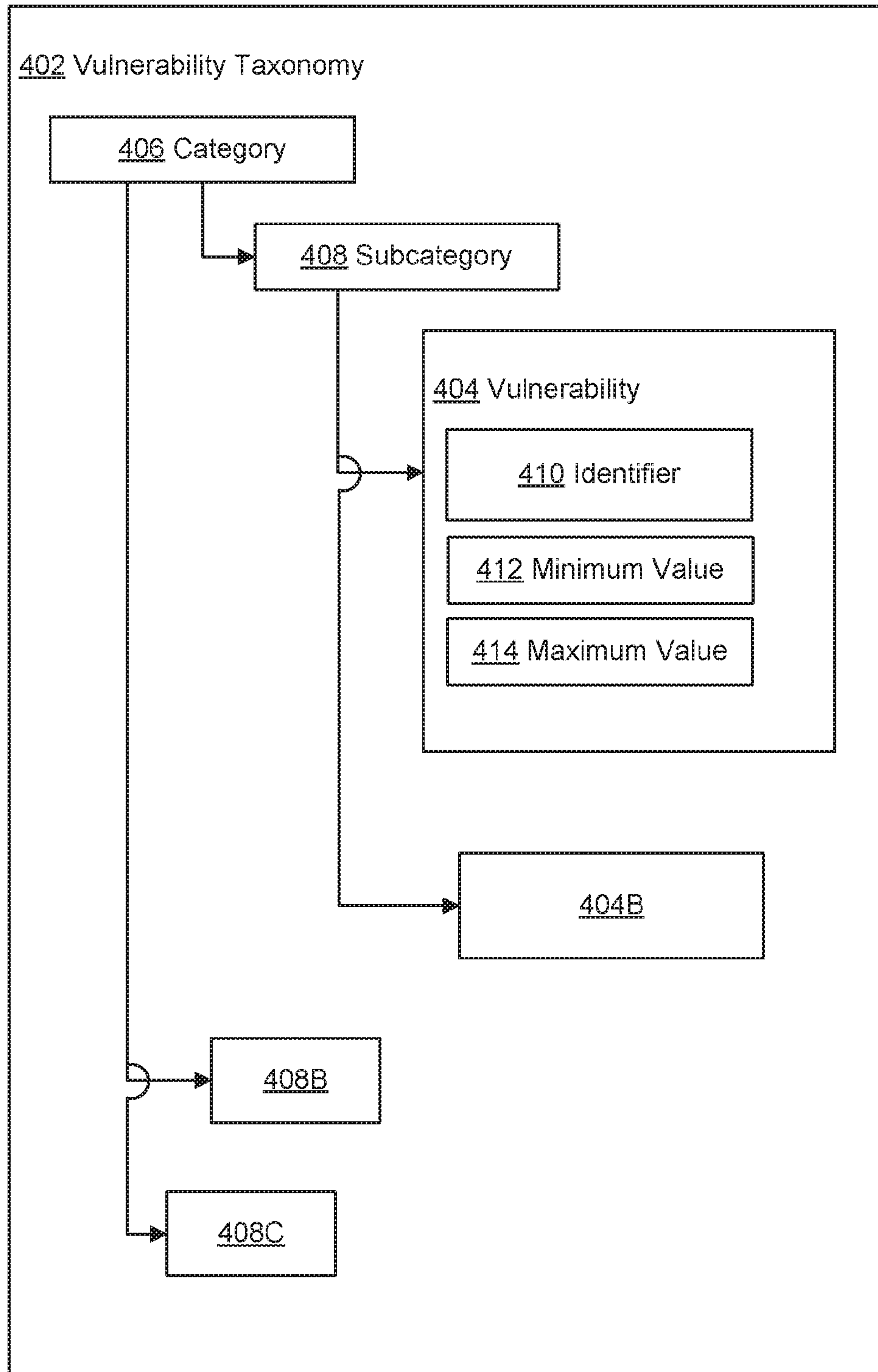


FIG. 3





**FIG. 4A**

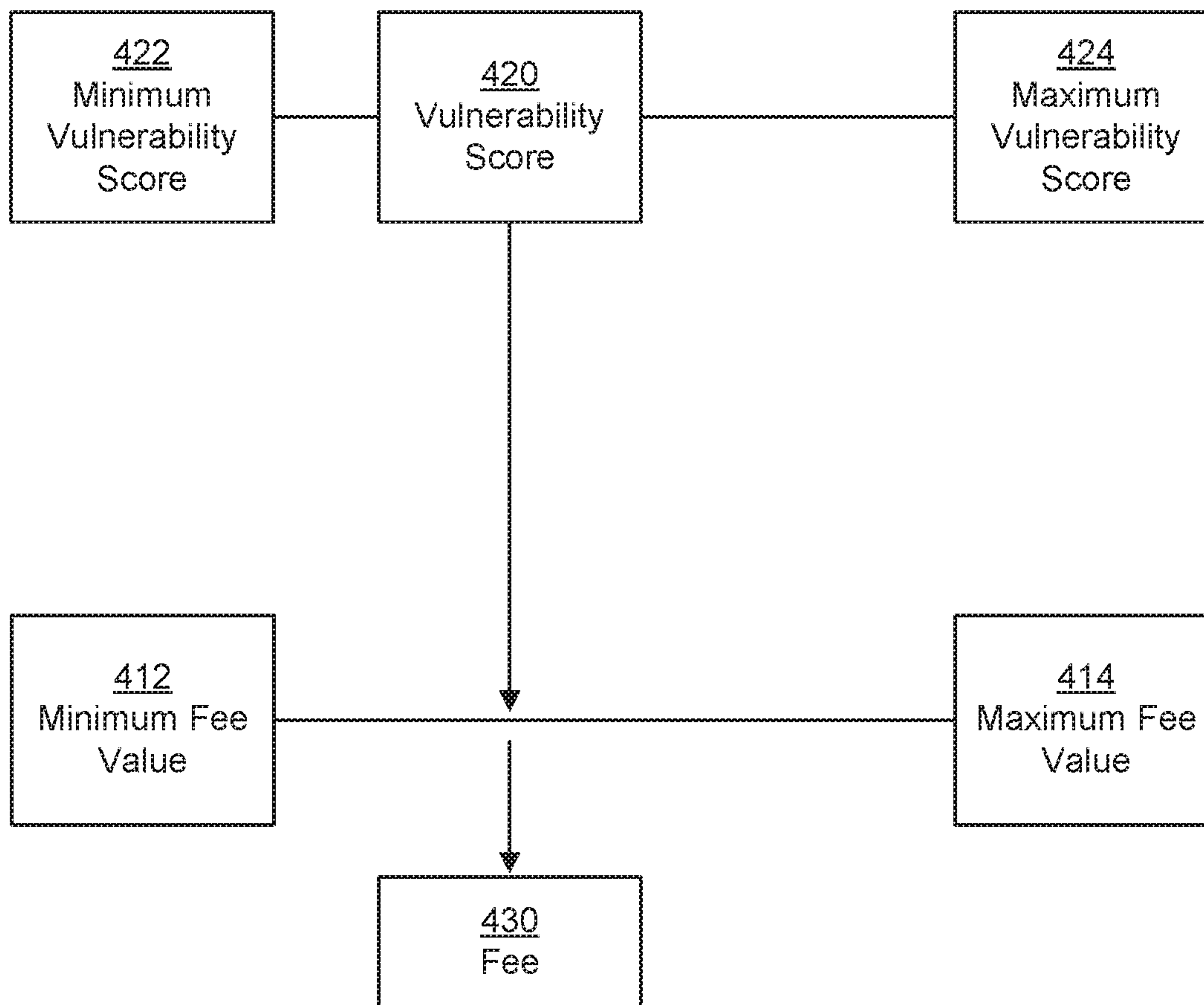


FIG. 4B

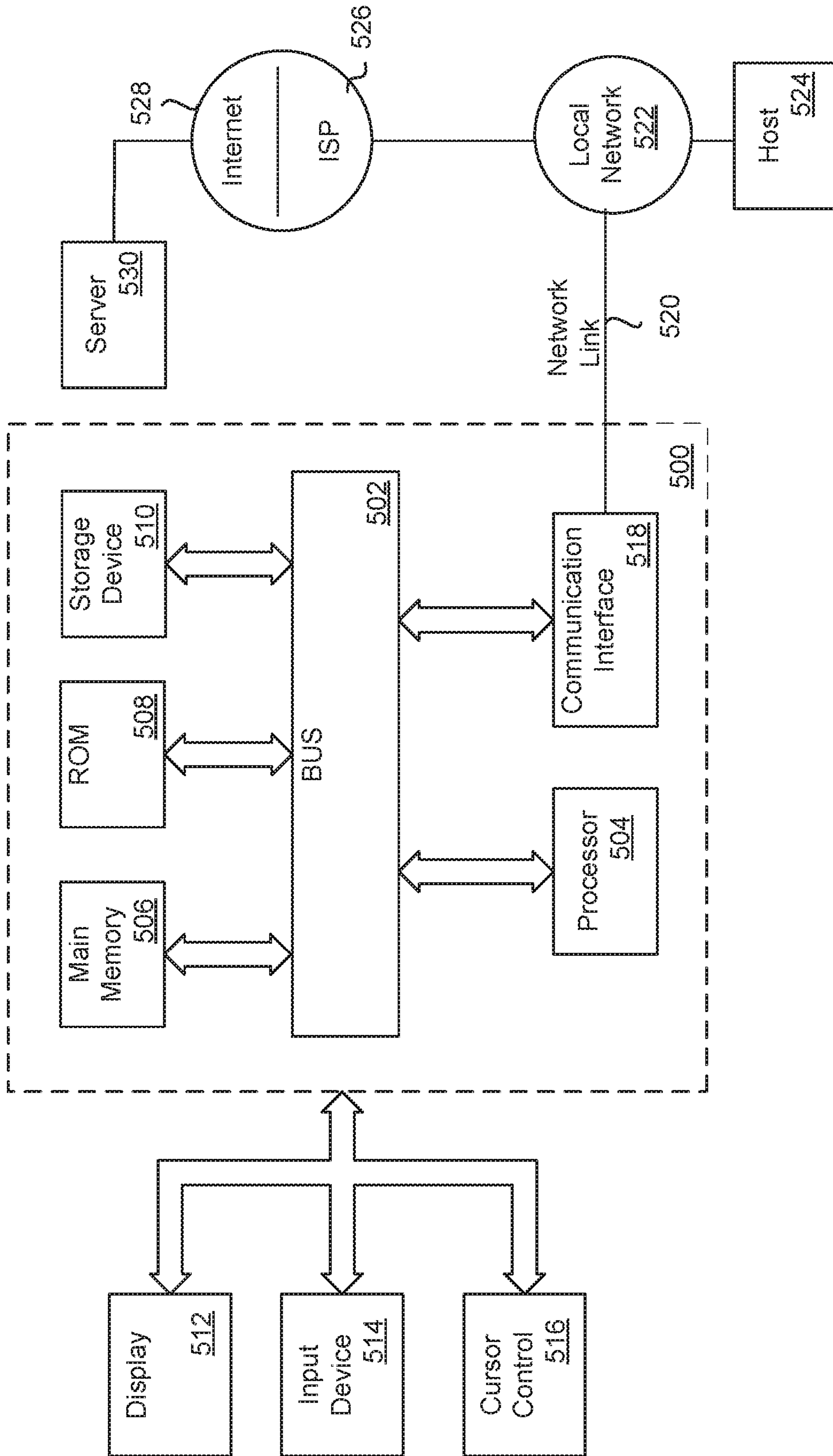


FIG. 5



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## COMPUTER SYSTEM FOR DISTRIBUTED DISCOVERY OF VULNERABILITIES IN APPLICATIONS

### CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 14/489,398, filed Sep. 9, 2015, now U.S. Pat. No. 9,350,753, which is a continuation of U.S. patent application Ser. No. 14/624,361, filed Feb. 17, 2015, now U.S. Pat. No. 9,177,156, which is a continuation of U.S. patent application Ser. No. 14/271,110, filed May 6, 2014, now U.S. Pat. No. 9,015,847, all of which are incorporated by reference herein for all purposes.

### FIELD OF THE DISCLOSURE

The present disclosure generally relates to testing of computers relating to security issues. The disclosure relates more particularly to techniques for performing network penetration testing, attack testing, identification of security vulnerabilities, and related security testing of web applications, server computers, and network elements.

### BACKGROUND

The approaches described in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

Present approaches for identifying security problems in networks have significant drawbacks. Typical network security evaluation, testing and protection involve installing protective elements in the network such as firewalls, virus and malware scanners, and similar systems. These systems receive reports of attack vectors that are occurring in other networks and attempt to determine if the same attacks are occurring in a particular network under test. If so, reports may be prepared and network administrators may manually examine the configuration of internetworking elements, web applications and server computers to determine whether configuration should be changed to remove a problem or prevent an attack.

However, a drawback of these approaches is that they are responsive, rather than preventive. Typically there are so many different kinds of attacks that it is considered impractical for a network administrator, or even a team of security professionals within a large enterprise, to exhaustively test all network elements and computing devices of the enterprise for vulnerability to all known attacks, malware and viruses. Therefore, in current practice many enterprise web applications, server computers and similar gear have a period of continued vulnerability until an actual security event is identified and addressed.

### SUMMARY

The appended claims may serve as a summary of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 illustrates a process of crowd-sourced application vulnerability discovery.

FIG. 2 illustrates an example computer system arrangement that may be used for crowd-sourced web application

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vulnerability discovery, providing globally distributed network penetration testing, and determining incentives for promoting the discovery of vulnerabilities.

FIG. 3 illustrates a process of application vulnerability discovery integrated with certain computer system elements of FIG. 2.

FIG. 4A illustrates a mapping of vulnerability categories, in a taxonomy, to ranges of incentive award amounts.

FIG. 4B illustrates determining an incentive award to a researcher for discovering a vulnerability.

FIG. 5 illustrates a computer system with which an embodiment may be implemented.

### DETAILED DESCRIPTION

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

Embodiments are described according to the following outline:

1. General Overview
2. Crowd-Sourced Application Vulnerability Discovery
3. System for Globally Distributed Crowd-Sourced Network Penetration Testing
4. Security Assessment Incentive Program For Promoting the Discovery of Computer Software Vulnerabilities
5. Implementation Example—Hardware Overview
6. Extensions and Alternatives

#### 1. General Overview

In one aspect, the disclosure provides: A method comprising: inviting a distributed plurality of researchers to participate in one or more computer vulnerability research projects directed to identifying computer vulnerabilities of one or more networks and/or computers that are owned or operated by a third party; assessing reputation and skills of one or more of the researchers, and accepting a subset of the researchers who have a positive reputation and sufficient skills to perform the investigations of the computer vulnerabilities; assigning a particular computer vulnerability research project, relating to a particular network under test, to a particular researcher from among the subset of the researchers; using a computer that is logically interposed between the particular researcher and the particular network under test, monitoring communications between the particular researcher and the particular network under test, wherein the communications relate to attempting to identify a candidate security vulnerability of the particular network under test; validating a report of the candidate security vulnerability of the particular network under test that is received from the particular researcher; determining and providing an award to the particular researcher in response to successfully validating the report of the candidate security vulnerability of the particular network under test that is received from the particular researcher.

In another aspect, the disclosure provides: A data processing method comprising: using a computer, inviting a distributed plurality of researcher computers to participate in one or more computer vulnerability research projects directed to identifying computer vulnerabilities of one or more networks and/or computers that are owned or operated



by a third party; using the computer, assigning a particular computer vulnerability research project, relating to a particular network under test, to a particular researcher computer from among a subset of the researcher computers; using control logic that is logically interposed between the particular researcher computer and the particular network under test, monitoring networked data communications between the particular researcher computer and the particular network under test, wherein the communications relate to attempting to identify a candidate security vulnerability of the particular network under test; validating a report of the candidate security vulnerability of the particular network under test that is received from the particular researcher computer; performing one or more remediation operations on the particular network under test based at least in part upon the report; wherein the method is performed using one or more computing devices.

In yet another aspect, the disclosure provides: A method comprising: inviting a distributed plurality of researchers to participate in one or more computer vulnerability research projects directed to identifying computer vulnerabilities of one or more networks and/or computers that are owned or operated by a third party; publishing, to the distributed plurality of researchers, a taxonomy of potential computer vulnerabilities, wherein each particular computer vulnerability in the taxonomy is associated with a range of award values; using a computer that is communicatively coupled to a particular researcher among the distributed plurality of researchers and a network under test among the one or more networks and/or computers, monitoring communications between the particular researcher and the particular network under test, wherein the communications relate to attempting to identify a candidate security vulnerability of the particular network under test; in response to a report of the candidate security vulnerability of the particular network under test that is received from the particular researcher, and based upon the taxonomy, determining and providing a particular award value to the particular researcher.

These approaches offer significant benefits over prior practice. In one embodiment, top global security talent previously inaccessible to enterprises can be recruited and incentivized through bounties to discover security vulnerabilities in a variety of target applications and systems. Security resources on a global scale can be safely engaged, and dynamic economics and gamification may be used to incentivize those performing work. Consequently, fees and rewards generate results, rather than generic reports.

In some embodiments, the system described herein can launch a full vulnerability assessment, leading to rapid results, in just a few hours. With little lead time, organizations can obtain rapid feedback, decreasing time to market and enabling patching vulnerabilities before it is too late. The approaches also can be scalable. By using global resources, the approaches can scale to a multitude of assessments at once. For enterprises with large applications or numerous web endpoints, the approaches herein provide a solution to obtain rapid results that are far more effective than traditional automated or manual solutions.

Embodiments also are configured to be adaptable. Assessments can be supported by industry experts who are well-versed in all technology stacks as they evolve. Testing, in embodiments, does not rely upon signatures but uses adversarial tactics to discover the latest zero-day vulnerabilities with methods that provide unique insight into attack vectors. Researchers undergo a strict verification and vetting process, and users of the services described herein can select from

among varying levels of trust and verification of the security researchers who conduct the work.

## 2. Crowd-Sourced Application Vulnerability Discovery

FIG. 1 illustrates a process of crowd-sourced application vulnerability discovery. In an embodiment, a party implementing the process of FIG. 1 may efficiently coordinate with a large number of globally distributed researchers to identify a variety of different computer vulnerabilities of target computers or hosts of a third party computer network. For example, the process of FIG. 1 may be implemented by a service provider that has a contract relationship with a plurality of globally distributed computer security researchers on the one hand, and that has a vendor-customer relationship to the third party owner or operator of a computer system that serves as the target of vulnerability investigation. Using such a three-party approach, including a large number of distributed researchers seeking to identify vulnerabilities in a controlled and monitored manner, computer vulnerabilities can be identified and investigated far faster and more efficiently than in prior approaches.

In one embodiment, at block 101, the process of FIG. 1 includes creating records of one or more projects to identify computer vulnerabilities of third parties. Block 101 broadly represents, for example, a service provider who implements FIG. 1 entering into a contract or other relationship with a third party that owns or operates a computer system or network, and creating records of computers, systems, applications, or other elements that the third party wishes to have evaluated for computer vulnerabilities. The third party and the service provider thus may have a customer-vendor relationship. "Computer vulnerabilities," in this context, includes any of security vulnerabilities, network vulnerabilities, opportunities or data breaches and the like for any of end station computers, server computers, cloud computing instances or resources, internetworking infrastructure such as routers, switches, firewalls and gateways, or other hardware devices, as well as logical or software entities such as database servers, application servers, or online applications such as web applications, mobile applications, etc. The service provider may work closely with organizations to create a project that best fits their budgetary constraints and technical requirements, including in some embodiments performing an initial assessment of the organization's security posture to ensure that the organization is well positioned for the commencement of crowd-sourced vulnerability testing.

Further, block 101 comprises creating records of specific projects to identify vulnerabilities. Project records may be defined by the service provider and the third party, for example, by preparing a topology or other description of specific assets in a network or among a set of computers that the third party desires to check or test.

In one embodiment, at block 102, the process of FIG. 1 includes inviting a distributed plurality of researchers to request participating in one or more projects to identify computer vulnerabilities of third parties. For example, a service provider may use online forums, message boards, e-mail lists, or its own website to promote the opportunity to participate in a crowd-sourced research project directed at computer vulnerabilities. Typically the identities of the third parties are known in advance, as the service provider will have entered into a contract with one or more third parties to provide consulting services, security investigation, or other services to the third party relating to the security



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posture of its network. However, typically the third parties are not identified at block **102** for purposes of confidentiality. Non-disclosure agreements and other rules of engagement may be implemented as part of bringing researchers onboard; for example, social engineering, DDos, and spam-based attacks may be prohibited, and organizations may define other rules of engagement for a specific area or technology.

In this context, “distributed plurality of researchers” refers to any number of researchers located anywhere in the world. Global or wide area distribution is not required, however. Typically the researchers are not employees of the party implementing the method; the researchers may be previously unknown to the party at the time of the invitation of block **102**, or may be known informally through security forums, conferences or other methods.

At block **104**, the process comprises assessing and enrolling one or more of the researchers in a computer vulnerability management system. Block **104** may include inspecting credentials of researchers who reply to the invitation of block **102**, determine reputation of the researchers, and creating data records in a computer database that identify the researchers and provide contact information, sources of reputation information, resumes or curricula vitae and like information. Assessment at block **104** also may comprise providing responsive researchers with one or more online tests or assessments to determine the level of skill or expertise of the researchers. For example, the party implementing FIG. **1** may maintain a networked computer system that has known vulnerabilities, and may provide responsive researchers with a network address and/or complete or partial login credentials for the system; the researchers then may be directed to attempt to find one or more security vulnerabilities in that system as a means of testing skill and knowledge. Block **104** also may involve updating the database with the results of the assessment.

At block **106**, the process comprises assigning a particular computer vulnerability research project to a particular researcher and optionally zero or more other researchers. For example, block **106** may comprise providing a summary of a record of a particular computer vulnerability research project among those that were defined at block **101**, and an access location that is associated with the service provider. In an embodiment, block **106** may involve providing a network address or domain address of a target computer to the researcher, and/or partial or complete access credentials for a computer or resource that is associated with the particular computer vulnerability research project. Additionally or alternatively, the particular researcher and any other researchers, are given access credentials or location data for a computer or application that is associated with the service provider, and the researchers then access the target computer or network of the particular vulnerability research project only through the service provider’s computer and/or application. In one embodiment, the means of access for researchers is termed a Launch Point; an example detailed description of a Launch Point is provided in other sections herein.

This information may be provided or offered to a particular researcher, or to a group of researchers. The number of researchers involved in a particular project is not limited and there may be benefits involved in assigning a single project to multiple unrelated or distributed researchers to encourage competition to find vulnerabilities. The particular steps or information involved in block **106** are not critical provided that one or more researchers obtain sufficient information to

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understand the nature and goals of a project, or the identity of a network location or computer that is to be investigated.

At block **108**, the process comprises inspecting, logging and monitoring communications between the researcher and a target computer system of the particular vulnerability research project. In general, the process is configured to permit the party implementing FIG. **1** to inspect, log, and/or monitor all electronic communications between the researchers who are assigned to a project and the target computers, networks or systems of the third party. This approach may permit the party implementing FIG. **1** to determine useful assessment data such as: the number of communications between the researcher and the target systems; whether the researcher appears to be actually addressing the subject matter of the particular vulnerability research project; whether the researcher is attempting to access resources of the third party for which access is prohibited or out of scope for the particular vulnerability research project; whether the researcher appears competent and/or diligent; and other metrics.

As an example, block **108** may include storing an audit trail of all URLs that the researcher sends to the target systems; keystroke logging other input of the researcher to the target systems; storing URLs of dynamically generated pages that the target systems may generate in response to action by a researcher; storing individual flow records and/or aggregated flow data based upon packet flow identifiers such as the TCP/IP **5**-tuple; storing sets of packets, segments, messages or request-response pairs based upon **5**-tuple or other identifying data; and any other data associated with communications between the researchers and the target systems.

At block **110**, the process receives a report of a candidate security vulnerability from a particular researcher. In one embodiment, a researcher who thinks s/he has identified a security vulnerability in a target system may submit a report that specifies the vulnerability and identifies the target system. Various formats may be used for submitting reports of apparent security vulnerabilities and the particular form of the report is not critical. An example is provided in another section herein.

At block **112**, the process comprises evaluating and attempting to duplicate the candidate security vulnerability that the researcher reported. For example, block **112** may involve re-performing a sequence of operations that are identified in the report, and/or re-performing a sequence of operations that were obtained via block **108**. At block **114**, the process tests whether the candidate security vulnerability was successfully validated. If not, then at block **122** a negative report or message may be communicated to the researcher, indicating that the vulnerability could not be validated, that further information is needed, or that the report appears to represent something other than a security vulnerability. The particular form and content of such a report or message is not critical.

If the test of block **114** is true, then several operations may be performed, sequentially in any order, or in parallel. At block **116**, in one embodiment, the process determines a fee to pay to the researcher. The fee at block **116** may be deemed an incentive award, bounty, service fee or any other form of payment. The fee may comprise value in a recognized hard currency, in an electronic currency such as Bitcoin, and/or in a virtual currency such as tokens, points, or other items that are redeemable in another program, system or facility. Specific techniques for determining the fee of block **116** are described in another section herein.



At block **118**, a notification may be provided to the third party. For example, a validated security vulnerability may be described in a report, message or other communication to the third party that owns or operates the network, computer or system that was the subject of the particular computer vulnerability research project. The particular form and content of such a report or message is not critical.

At block **120**, the process comprises performing host assessment or other remedial action. For example, block **120** may comprise performing one or more security remediation operations on a host that the researcher identified in the report of block **110**, such as installing software updates, changing configuration data, reconfiguring a position of a unit in a network topology, updating the configuration of automatic attack detection systems such as intrusion detection systems, and other operations.

As a result, the approach of FIG. **1** may lead to more rapid identification and remediation of vulnerability issues in computers or networks by providing a way to induce a potentially large number of distributed researchers to attempt attacks, intrusions, or other exploitation of vulnerabilities of the computer or networks, optionally in return for a fee, award or other recognition. A party implementing FIG. **1**, such as a service provider, serves as an intermediary between the distributed researchers and the target computers or networks, so that all communications of the researchers—which may include actual attack attempts—can be inspected, monitored and logged. Further, the third party that owns or operates the network that is the subject of an investigation can receive reports, remediation operations, and/or configuration data based upon the work of the distributed researchers after validation by the service provider. All these features and aspects may provide a greatly improved, more efficient and more effective process for identifying and addressing computer vulnerabilities.

### 3. System for Globally Distributed Crowd-Sourced Network Penetration Testing

FIG. **2** illustrates an example computer system arrangement that may be used for crowd-sourced web application vulnerability discovery, providing globally distributed network penetration testing, and determining incentives for promoting the discovery of vulnerabilities. FIG. **3** illustrates a process of application vulnerability discovery integrated with certain computer system elements of FIG. **2**. Referring first to FIG. **2**, in one embodiment, a plurality of researcher computers **202** are coupled via one or more networks and/or internetworks to a Launch Point computer **206**. An automated scanning system **204**, management computer **207**, vulnerability database **250**, and one or more networks under test **208**, **228** also are communicatively coupled to the Launch Point computer **206**. For purposes of illustrating a clear example, FIG. **2** shows a limited number of researcher computers **202**, automated scanning system **204**, network under test **208**, **228**, computer under test **226**, **230**, and client units **220**, **222**, but in practical embodiments the number of such units is not limited; embodiments may interoperate with at least thousands of distributed researchers with computers and with any number of customer networks under test having any number of computers or other nodes under test.

In an embodiment, each of the researcher computers **202** is associated with one of a plurality of distributed researchers of the type previously described. The researcher computers **202** may comprise any of desktop computers, workstations, laptop computers, netbook computers, ultrabook computers, tablet computers or smartphones. The researcher

computers **202** are coupled indirectly to the Launch Point computer **206** by any combination of one or more local area networks, wide area networks, internetworks and the like, which may include the public internet.

Launch Point computer **206** comprises, in one embodiment, one or more client units **220**, **222**, and may be coupled to a management computer **207** comprising control logic **224** and fee computation logic **214** and coupled to a vulnerability database **250**. In an embodiment, the Launch Point computer **206** acts as a terminal that is configured for the purposes of providing network connectivity and monitoring for communications between researcher computers **202** and the networks under test. Moreover, the logical position of Launch Point computer **206** between the researcher and the network under test provides secure routing of researcher communications to networks under test and provides a predictable source IP address for the owner/operator of the network under test, to enable adjustment of firewalls and/or IPS/IDS devices.

In an embodiment, each of the client units **220**, **222** is configured to communicate to a different computer under test **226**, **230** located respectively in a different network under test **208**, **228**. Each client unit **220**, **222** thus is configured to cooperate with Launch Point computer **206** in acting as an intermediary between one or more of the researcher computers **202** and one of the networks under test **208**, **228** and/or one of the computers under test **226**, **230**. As indicated by arrow **290**, each of the researcher computers **202** may establish a logical bidirectional communication path to one or more of the networks under test **208**, **228**, with all communications passing through Launch Point computer **206** for purposes of controlling which particular researcher computers are connected to which particular network under test and for monitoring, logging and/or analysis. As further described herein, control logic **222** may be configured to provide a particular researcher computer **202** with access to a particular network under test **208**, **228** only under specified circumstances including after assessment, testing, assignment of a project, or other operations. Thus, researcher computers **202** typically cannot contact the networks under test **208**, **228** at will; instead, the Launch Point computer **206** must facilitate access, grant access or provide credentials.

Control logic **224** is configured, in an embodiment, to implement the control functions and management functions that are described further herein. Fee computation logic **214** is configured, in an embodiment, to determine a fee, award, bounty or other payment, value or currency that is due or payable to one of the researchers in consideration for identifying a vulnerability of one of the computers under test **226**, **230** or networks under test **208**, **228**. Techniques for computing applicable fees are described herein in other sections. Each of the control logic **224** and fee computation logic **214** may be implemented using one or more computer programs, other software elements, other digital logic as described for FIG. **5**, or any combination thereof.

An automatic scanning system **204** may be coupled to one or more of the networks under test **208**, **228** and/or to one or more of the computers under test **226**, **230** and may generate one or more reports **205** based upon performing automatic scanning operations on those networks or computers. The reports **205** may be received at vulnerability database **250** to provide baseline vulnerability data or to assist in defining the computer vulnerability projects that may be offered to researchers. Additionally, in an embodiment, control logic **224** may implement a feedback loop in relation to automatic scanning system **204** by which the control logic provides updates to configuration data or other input to the automatic



scanning system, based upon validated vulnerability reports from researchers, to improve the ability of the automatic scanning system to detect other vulnerabilities in the future in relation to the networks under test **208**, **228** or the computers under test **226**, **230**.

A vulnerability database **250** may be coupled to Launch Point computer **206** and may be configured to store metadata or substantive data about researchers, researcher computers **202**, client units **220**, **222**, networks under test **208**, **228**, computers under test **226**, **230**, and other data useful to support operation of the system. In an embodiment, management computer **207** or another computer may host a web application that enables clients and researchers to collaborate regarding fixing vulnerabilities that have been input to the vulnerability database **250**.

A particular network under test **228** may be coupled to an administrator computer **240** that is associated with a network administrator for that network. In an embodiment, control logic **224** is configured to receive one or more requests **260** from the administrator computer **240** via a client web interface hosted at management computer. The requests typically relate to performing vulnerability tests on the associated network under test **228**, or the computer under test **230** within that network or other nodes of that network. Control logic **224** also may be configured to generate and send one or more reports **270** to the administrator computer **240** relating to security vulnerabilities that have been identified in the associated network under test **228**, or the computer under test **230** within that network or other nodes of that network.

Thus, it may be seen from FIG. **2** that embodiments may provide a Launch Point computer **206** associated with a first party, logically arranged as an intermediary between the researcher computers **202** associated with second parties and the networks under test **208**, **228** and computers under test **226**, **230** of third parties. Input from the Launch Point computer **206** may be used to update an automatic scanning system **204** to improve its performance, and administrators associated with administrator computer **240** may receive reports about vulnerabilities that are found.

Referring now to FIG. **3**, in an embodiment, a process of crowd-sourced application vulnerability discovery may be integrated with selected technical elements of FIG. **2** to efficiently coordinate with a large number of globally distributed researchers to identify a variety of different computer vulnerabilities of target computers or hosts of a third party computer network.

At block **302**, invitation and assessment is performed. In an embodiment, a party implementing FIG. **3** takes steps to identify and invite researchers, and in some embodiments block **302** may represent performing blocks **101**, **102**, **104** of FIG. **1** as described above. Assessment may include investigation of social media postings of candidate researchers and other online sources of data to determine, for example, that a particular researcher is a so-called white hat hacker and not a malicious computer user. Assessment may include an interview process, which may comprise in part a live interview of the candidate researcher, background checks of the candidate researcher, skill tests, identity verification, and other investigation. Assessment further may comprise performing a randomized technical exam of a candidate researcher in which the researcher is required to classify issues relating to web application security, mobile application security, infrastructure, and other issues. A practical assessment of skills in this manner may serve as a precondition for receiving an invitation to join a team of researchers. Results may be used to segment researchers into various

trust categories based upon user requirements; the level of trust can be used to affect the amount of a bounty that is later calculated.

In an embodiment, block **302** also may involve storing data that segments or classifies the researcher based upon citizenship, levels of permissible government access, residence or domicile, or other factors; the database **250** may be updated with tags in records that identify researchers for these attributes.

At block **304**, assignment of a project occurs. In an embodiment, block **304** presumes that the service provider operating Launch Point computer **206** and the third party of network under test **208**, **228** have defined one or more computer vulnerability projects. Defining projects may comprise, for example, by preparing a topology or other description of specific assets in the network under test **208**, **228** that the third party desires to check or test and creating records of projects in database **250**. Additionally or alternatively, the automated scanning system **204** may provide reports **205** that may suggest vulnerabilities or indicate anomalies that indicate that vulnerabilities exist; data in the reports may be used to form records of projects for investigation.

Block **304** may include the operations of block **106** described above. Further, assignment of a project may comprise granting access to a researcher to a web portal for web applications that are within the scope of the project. The web portal may provide, for example, a screen view that displays the identity and general content of computers, networks or other resources that are within the scope of a particular vulnerability research project. Typically, the identity of customers of the party that implements FIG. **3** are anonymized so that researchers are not aware of exactly whom they are attacking, to prevent the introduction of bias into the vulnerability detection process. In one embodiment, assignment of a project may include receiving a sign-up request for a specific project or target. Obtaining agreement of the researcher to a customer-specific confidentiality agreement may be required as part of the assignment process.

At block **306**, the project is initiated by the researcher and the party implementing FIG. **3** receives one or more reports of computer vulnerabilities within the scope of the assigned project. Block **306** may represent the operation of blocks **106**, **108**, **110** of FIG. **1** as described above. Further, in one embodiment, initiating a project comprises instantiating a virtual machine in a shared data center, such as a cloud computing facility, that implements the Launch Point computer **206** as a server instance or other computing instance. Thus, the Launch Point computer **206** may be spun up on demand. Any such server may be instantiated at a geographical location that is based upon a location of the particular researcher who is involved in a project; thus, for example, if the service provider who implements FIG. **3** is located in Los Angeles, the network under test **208** is located in New York, and the researcher computer **202** of a researcher assigned to that network is located in Miami, then the Launch Point computer **206** might be spun-up preferably at a data center in Atlanta or Miami rather than a data center in New York or Los Angeles.

Block **306** further comprises monitoring and optionally logging all tests, messages and between an assigned researcher computer **202** and a target network or computer; thus, all tests funnel through the infrastructure of the service provider to permit logging activity and capturing actions taken by a researcher.

Reports of vulnerabilities may be received periodically from any of the researchers who are assigned to a project. In



an embodiment, data comprising a vulnerability report is received in the same view or user interface facility that is used to obtain data about projects, target computers and target networks. In an embodiment, to report a prospective vulnerability, the researcher enters a category value and optionally a sub category value for the vulnerability that they are reporting. The category and sub category values are deemed proposed and are subject to validation by the service provider. In some embodiments, reporting a prospective vulnerability may comprise receiving data values in fields of a submission form. As an example, a submission form may comprise data fields for: Title; Description; Vulnerability Category, which may be selected from a drop-down menu or other GUI widget; Steps to Reproduce the vulnerability; Impact of the vulnerability; Secret gist for one or more codes that were used to determine the vulnerability; Recommended Fix; and URL identifier for a URL at which the vulnerability exists.

In some embodiments, reporting a proposed vulnerability also comprises receiving answers to a questionnaire.

Examples of questions include:

1. Is an authenticated login required? Yes, No.
2. What is the impact to confidentiality? None, Yes for a single user, Yes for more than one user.
3. Is the integrity of application or user data compromised? No, Yes for a single user, Yes for more than one user.
4. Could this vulnerability have any impact on application availability? No, Yes for a single user, Yes for more than one user.

At block 308, the reported vulnerability is evaluated and validated, which may include the operation of blocks 112, 114 of FIG. 1. In an embodiment, evaluation of a vulnerability may comprise deduplication, which involves checking whether another researcher has previously reported the identical vulnerability or a substantially similar vulnerability. Deduplication may comprise performing a literal or fuzzy comparison of the values received in response to the questionnaire, and other data received from the researcher about the suggested vulnerability, to records of previously reported vulnerabilities in database 250. Evaluation of a vulnerability also may comprise verifying the quality of a submission and requesting more information if needed. Evaluation of a vulnerability also may comprise validating the report by re-performing the exact attack that was reported to check that what the researcher reported is a genuine vulnerability.

At block 310, the process determines a fee to be paid to the researcher who reported the proposed vulnerability as noted above for block 116. In one approach, block 310 is configured, based on the answers that were received to the questionnaire described above, to calculate a vulnerability score such as a CVSS score, and to map the category and subcategory of vulnerability and the CVSS score to a minimum price and a maximum price. The CVSS score may be scaled linearly to a price between the minimum and maximum price, using a stored mapping to a price for a bounty to be paid. Typically a score value of 0 maps to the minimum price and a score value of 10.0 maps to the maximum price, after summing all the CVSS components. In this manner, embodiments can provide a real-time, market value calculation for the value of a reported vulnerability.

For purposes of determining fees, deduplication and other purposes, the control logic may be configured to manage a vulnerability taxonomy in the database 150 that associates categories, subcategories, vulnerability names, and a range of fees. FIG. 4A illustrates an example vulnerability taxonomy, and FIG. 4B illustrates an example mapping of a

particular vulnerability score to a particular fee. Referring first to FIG. 4A, in one embodiment, a vulnerability taxonomy 402 comprises a plurality of any number of categories 406, 406B, 406C. A category 406 may have any number, including zero, of subcategories 408, 408B, 408C. A category 406 or a subcategory 408 may be associated with one or more vulnerabilities 404, of which one is shown in FIG. 4A for purposes of illustrating a clear example.

In an embodiment, a particular vulnerability 404 comprises an identifier 410, a minimum value 412 and a maximum value 414. The identifier 410 may be any label that enables human and/or machine recognition of a particular vulnerability. Identifier 410 may comprise a value that is usable in programmatic operations, or a displayable name, or both. The minimum value 412 represents a minimum amount of a fee that is payable to a researcher for identifying the associated vulnerability in a target system; the maximum value 414 represents a maximum of such a fee. The minimum value 412 and the maximum value 414 may be represented using any form of units. In one embodiment, integers representing US dollars are used.

Referring now to FIG. 4B, in an embodiment, the minimum value 412 and maximum value 414 may be used as endpoints of a fee range. The vulnerability score 420 for a particular vulnerability, which may be determined using CVSS or other scoring, also lies within a separate range having a minimum score value 422 and a maximum score value 424. In an embodiment, the particular vulnerability score 420 is linearly mapped from its position in the range of score values to an equivalent position in the range of fees, resulting in selection or computation of a particular fee 430 for the associated vulnerability having the particular vulnerability score 420.

Computation of a CVSS score may be performed according to NIST standards, using the following expressions:

$$\text{BaseScore} = (0.6 * \text{Impact} + 0.4 * \text{Exploitability} - 1.5) * f(\text{Impact})$$

$$\text{Impact} = 10.41 * (1 - (1 - \text{ConfImpact}) * (1 - \text{IntegImpact}) * (1 - \text{AvailImpact}))$$

Exploitability = 20 \* AccessComplexity \* Authentication \* AccessVector  
where the following variables have the following values:

access\_complexity: 0.61

access\_vector: 1.0

authentication:

question: "Is an authenticated login required?"; answers: "Yes.": 0.56; "No.": 0.704

confidentiality\_impact:

question: "What is the impact to confidentiality?"; answers: "None.": 0.0; "Yes, for a single user.": 0.275; "Yes, for more than one user.": 0.660

integrity\_impact:

question: "Is the integrity of application or user data compromised?"; answers: "No.": 0.0; "Yes, for a single user.": 0.275; "Yes, for more than one user.": 0.660

availability\_impact:

question: "Could this vulnerability have any impact on application availability?"; answers: "No.": 0.0; "Yes, for a single user.": 0.275; "Yes, for more than one user.": 0.660

The following is an example description of a vulnerability that is nested one level down in a taxonomy of vulnerabilities and is associated with particular specified prices:

sql\_injection:

display: "SQL Injection"

poorly\_filtered\_strings:



display: "Poorly Filtered Strings" min: 1500.0 max: 2000.0

The resulting price may be provided to the researcher and existing payment networks or other transfer systems may be used to convey a fee equal to the price, or other items or virtual currency, to the researcher. In an embodiment, pricing is standardized regardless of customer; this sets expectations among the researcher community so they always know if they find a particular hard vulnerability that they will get a specified amount.

Referring again to FIG. 3, in an embodiment, at block 322, the process provides a notification to the customer as generally described above for block 118 of FIG. 1. In an embodiment, the Launch Point computer 206 may host an application program, web server or the equivalent that provides a separate portal into which a customer of the service provider may log into. In an embodiment, the customer portal provided by management computer 207 may enable customers to obtain and display, via administrator computer 240 for example, a view of vulnerabilities that have been identified by the researcher computers 202, organized according to particular assets within a network under test 208. Assets, in this context, may comprise computers, elements of networking infrastructure, applications, or other nodes or items. The customer portal may enable, in one embodiment, the customer to change the status of a particular vulnerability to identify remediation steps that the customer has undertaken for an associated asset or for the vulnerability as a whole. In an embodiment, the control logic 224 may be configured to export data representing vulnerability reports and/or remediation efforts to a bug tracking application, such as JIRA, commercially available from Atlassian Pty Ltd., Sydney, Australia.

In an embodiment, control logic 224 may be configured to facilitate direct communication between administrator computer 240 and a particular researcher computer 202 that is associated with a researcher who identified a particular vulnerability. In such an embodiment, Launch Point computer 206 may act as an intermediary for such communications and may log messages or serve as a message store-and-forward service with which the administrator computer 240 may compose a message and request dispatch to the particular researcher computer 202. In this manner, the administrator computer 240 of a particular customer of the Launch Point computer 206 may re-engage the researcher computer 202, for example, to request a re-validation to check if a particular vulnerability was successfully corrected or patched as a result of remediation operations that the customer performed. In some embodiments, the management computer 207 or another system may convey a fixed fee to the researcher computer 202 in consideration for such a re-evaluation.

In an embodiment, at block 314 of FIG. 3, the process prepares feedback data and provides the feedback data to the database 240 and/or to the automatic risk scanners 204. For example, control logic 224 may be configured to transform a specific vulnerability into a generic description of the vulnerability so that the same class or type of vulnerability can be found in other apps of the same type. The generic description may be formatted according to a general protocol or may be expressed in terms of operations, syntax, semantics, or configuration data that is compatible with a particular one or more of the automated risk scanners 204. In this manner, a particular vulnerability that is identified by any of the researcher computers 202 may be used to update

the automated vulnerability scanners 204 so that finding new vulnerabilities becomes more difficult for the researcher computers over time.

At block 316, one or more host assessment operations may be performed, as generally noted above for block 120 of FIG. 1. In one embodiment, host assessment comprises generating one or more sets of fingerprint data that represent a hardware configuration and software configuration or posture of a particular asset in a network under test 208. In an embodiment, the fingerprint data may represent configuration of an asset at the patch level, and the fingerprint data may be provided to the automatic vulnerability scanners 204 to permit improved scanning of hardware, software and services. Any form of signature data may be used, pertaining for example to application semantics.

#### 4. Security Assessment Incentive Program for Promoting the Discovery of Computer Software Vulnerabilities

Embodiments may be used to implement incentive programs to induce or encourage the researcher computers 202 to locate vulnerabilities. In one embodiment, as described above for FIG. 1 and FIG. 3, a process of identifying computer vulnerabilities may integrate the offering, determination and payment of fees to researchers as an inducement to discovery vulnerabilities. The inducement benefit of such a method may be enhanced, in one embodiment, by publishing an approximate range of fees that will be paid and information about how a vulnerability score of a particular vulnerability is mapped within the range to yield a particular fee. In this manner, researchers in the field receive objectively understandable information about how a fee will be determined and paid, which should improve confidence in the overall method and system.

In another embodiment, the methods of FIG. 1, FIG. 3 may be supplemented with gamification operations. For example, in one embodiment, the methods of FIG. 1, FIG. 3 also include, and/or the control logic 224 is configured to provide, assigning a quantity of points to a particular vulnerability, rather than only a fee. For example, metadata representing a vulnerability as seen in FIG. 4A also may include a minimum points value and a maximum points value, and the process of FIG. 4B also may include determining a particular points value for a particular vulnerability by mapping the vulnerability score within a range of points defined by the minimum points value and maximum points value. Determining the particular points value may use a linear mapping or a non-linear, weighted and/or scaled mapping in various embodiments. In one embodiment, the mapping may use a blended mapping function that blends values for vulnerability score, a submission quality score that represents the quality of a vulnerability report or submission, a perceived value of the asset in the network under test 208, and/or other values.

Further, FIG. 1, FIG. 3, and/or control logic 224 may be configured to create, store and/or cause displaying a leaderboard that identifies the researcher computers 202 and the total points or particular points values that the researchers have earned or obtained. Researcher computers 202 may be identified using pseudonyms, screen names or handles.

FIG. 1, FIG. 3, and/or control logic 224 may be configured to determine one or more prizes that are awarded to the researcher computer 202 or researcher who achieves the highest number of points within a particular award period such as within a particular month.



FIG. 1, FIG. 3, and/or control logic 224 may be configured to create, store and/or cause displaying data representing accomplishment levels for particular researcher computers 202 based upon total points that are earned by or awarded to the researchers. For example, a particular achievement may be associated with identifying a particular number of vulnerabilities, earning a particular number of points, or earning fees at a particular total amount. Each achievement may be associated with a graphical icon such as a badge, or may be associated with a prize, fee, virtual currency, admission to an event, or other award or recognition for the researcher or researcher computer 202.

FIG. 1, FIG. 3, and/or control logic 224 may be configured to facilitate redemption of points for things that are consistent with the white-hat role of the researcher computers 202. For example, FIG. 1, FIG. 3, and/or control logic 224 may be configured to facilitate redeeming points awarded in any of the foregoing embodiments for travel, gifts, dining, or other things. FIG. 1, FIG. 3, and/or control logic 224 may be configured to perform transfer of points earned using the methods or system to external systems, including loyalty points systems, using electronic interfaces to those systems and according to specified transfer ratios that transform points earned for finding computer vulnerabilities into airline points, hotel points, dining points, or other kinds of points of third-party systems.

#### 5. Implementation Example Hardware Overview

According to one embodiment, the techniques described herein are implemented by one or more special-purpose computing devices. The special-purpose computing devices may be hard-wired to perform the techniques, or may include digital electronic devices such as one or more application-specific integrated circuits (ASICs) or field programmable gate arrays (FPGAs) that are persistently programmed to perform the techniques, or may include one or more general purpose hardware processors programmed to perform the techniques pursuant to program instructions in firmware, memory, other storage, or a combination. Such special-purpose computing devices may also combine custom hard-wired logic, ASICs, or FPGAs with custom programming to accomplish the techniques. The special-purpose computing devices may be desktop computer systems, portable computer systems, handheld devices, networking devices or any other device that incorporates hard-wired and/or program logic to implement the techniques.

For example, FIG. 5 is a block diagram that illustrates a computer system 500 upon which an embodiment of the invention may be implemented. Computer system 500 includes a bus 502 or other communication mechanism for communicating information, and a hardware processor 504 coupled with bus 502 for processing information. Hardware processor 504 may be, for example, a general purpose microprocessor.

Computer system 500 also includes a main memory 506, such as a random access memory (RAM) or other dynamic storage device, coupled to bus 502 for storing information and instructions to be executed by processor 504. Main memory 506 also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor 504. Such instructions, when stored in non-transitory storage media accessible to processor 504, render computer system 500 into a special-purpose machine that is customized to perform the operations specified in the instructions.

Computer system 500 further includes a read only memory (ROM) 508 or other static storage device coupled to bus 502 for storing static information and instructions for processor 504. A storage device 510, such as a magnetic disk or optical disk, is provided and coupled to bus 502 for storing information and instructions.

Computer system 500 may be coupled via bus 502 to a display 512, such as a cathode ray tube (CRT), for displaying information to a computer user. An input device 514, including alphanumeric and other keys, is coupled to bus 502 for communicating information and command selections to processor 504. Another type of user input device is cursor control 516, such as a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor 504 and for controlling cursor movement on display 512. This input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), that allows the device to specify positions in a plane.

Computer system 500 may implement the techniques described herein using customized hard-wired logic, one or more ASICs or FPGAs, firmware and/or program logic which in combination with the computer system causes or programs computer system 500 to be a special-purpose machine. According to one embodiment, the techniques herein are performed by computer system 500 in response to processor 504 executing one or more sequences of one or more instructions contained in main memory 506. Such instructions may be read into main memory 506 from another storage medium, such as storage device 510. Execution of the sequences of instructions contained in main memory 506 causes processor 504 to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions.

The term “storage media” as used herein refers to any non-transitory media that store data and/or instructions that cause a machine to operation in a specific fashion. Such storage media may comprise non-volatile media and/or volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device 510. Volatile media includes dynamic memory, such as main memory 506. Common forms of storage media include, for example, a floppy disk, a flexible disk, hard disk, solid state drive, magnetic tape, or any other magnetic data storage medium, a CD-ROM, any other optical data storage medium, any physical medium with patterns of holes, a RAM, a PROM, and EPROM, a FLASH-EPROM, NVRAM, any other memory chip or cartridge.

Storage media is distinct from but may be used in conjunction with transmission media. Transmission media participates in transferring information between storage media. For example, transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise bus 502. Transmission media can also take the form of acoustic or light waves, such as those generated during radio-wave and infra-red data communications.

Various forms of media may be involved in carrying one or more sequences of one or more instructions to processor 504 for execution. For example, the instructions may initially be carried on a magnetic disk or solid state drive of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to computer system 500 can receive the data on the telephone line and use an infra-red transmitter to convert the data to an infra-red signal. An infra-red detector can receive the data carried in



the infra-red signal and appropriate circuitry can place the data on bus 502. Bus 502 carries the data to main memory 506, from which processor 504 retrieves and executes the instructions. The instructions received by main memory 506 may optionally be stored on storage device 510 either before or after execution by processor 504.

Computer system 500 also includes a communication interface 518 coupled to bus 502. Communication interface 518 provides a two-way data communication coupling to a network link 520 that is connected to a local network 522. For example, communication interface 518 may be an integrated services digital network (ISDN) card, cable modem, satellite modem, or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, communication interface 518 may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface 518 sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

Network link 520 typically provides data communication through one or more networks to other data devices. For example, network link 520 may provide a connection through local network 522 to a host computer 524 or to data equipment operated by an Internet Service Provider (ISP) 526. ISP 526 in turn provides data communication services through the world wide packet data communication network now commonly referred to as the "Internet" 528. Local network 522 and Internet 528 both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link 520 and through communication interface 518, which carry the digital data to and from computer system 500, are example forms of transmission media.

Computer system 500 can send messages and receive data, including program code, through the network(s), network link 520 and communication interface 518. In the Internet example, a server 530 might transmit a requested code for an application program through Internet 528, ISP 526, local network 522 and communication interface 518.

The received code may be executed by processor 504 as it is received, and/or stored in storage device 510, or other non-volatile storage for later execution.

## 6. Extensions and Alternatives

In the foregoing specification, embodiments of the invention have been described with reference to numerous specific details that may vary from implementation to implementation. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. The sole and exclusive indicator of the scope of the invention, and what is intended by the applicants to be the scope of the invention, is the literal and equivalent scope of the set of claims that issue from this application, in the specific form in which such claims issue, including any subsequent correction.

What is claimed is:

1. A method of computer vulnerability discovery comprising:

determining a plurality of researcher computers that are to be provided access to control logic, wherein a researcher computer of the plurality of researcher computers is a computer operated by, or to be operated by, an invited researcher, wherein an invited researcher is a person or organization selected to participate in one

or more computer vulnerability research projects directed to researching and/or identifying computer vulnerabilities of one or more target systems comprising one or more network component and/or one or more computer component, wherein the control logic is capable of monitoring at least some communications between the researcher computer and the one or more target systems;

tracking assignment of a particular computer vulnerability research project of the one or more computer vulnerability research projects to an assigned researcher computer, to be operated by the invited researcher assigned to the particular computer vulnerability research project, wherein the particular computer vulnerability research project relates to a particular target system; providing the assigned researcher computer with access credentials for the control logic and/or the particular target system; establishing a communications path between the control logic and the particular target system; monitoring networked data communications between the researcher computer and the particular target system, wherein the networked data communications include communications that are usable to identify a candidate vulnerability of the particular target system; and determining a candidate vulnerability of the particular target system based on a report received from the assigned resulting from the assigned researcher's use of the assigned researcher computer to interact with the particular target system.

2. The method of claim 1, further comprising:

receiving the report; attempting duplication of the candidate vulnerability after receiving the report; validating the report of the candidate vulnerability of the particular target system if the candidate vulnerability is successfully duplicated; and invalidating the report of the candidate vulnerability of the particular target system if the candidate vulnerability is not successfully duplicated.

3. The method of claim 1, further comprising:

assigning the particular computer vulnerability research project to a first researcher computer of the plurality of researcher computers; assigning the particular computer vulnerability research project to a second researcher computer of the plurality of researcher computers; using the control logic, monitoring first communications between the first researcher computer and particular target system; using the control logic, monitoring second communications between the second researcher computer and particular target system; for the candidate vulnerability of the particular target system, determining which of the first researcher computer and the second researcher computer is a first reporting computer that first reported the candidate vulnerability; determining an award for discovery of the candidate vulnerability; and providing the award only to the researcher associated with the first reporting computer.

4. The method of claim 1, further comprising:

obtaining a customer-selected subset of researchers selected by an operator of the particular target system; and



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identifying a researcher computer subset comprising researcher computers of the plurality of researcher computers that are researcher computers associated with the customer-selected subset of researchers, wherein providing access credentials comprises providing access credentials for vulnerability testing of the particular target system only to the researcher computers associated with the customer-selected subset of researchers.

5. The method of claim 4, further comprising providing the operator of the particular target system with levels of trust for the plurality of researcher computers and representations of particular skill sets of researchers associated with the plurality of researcher computers, for use in selecting a subset of researchers.

6. The method of claim 1, further comprising: performing an initial assessment of security aspects of the particular target system prior to testing the particular target system; based on the initial assessment, determining which site-specific computer vulnerability research projects to assign and which candidate researchers would become assigned researchers; and assigning site-specific computer vulnerability research projects to the assigned researchers.

7. The method of claim 6, further comprising: assessing the assigned researchers according to social media postings of the candidate researchers and/or other online sources of data authored by the assigned researchers; and determining, from the social media postings and/or the other online sources of data, whether each of the assigned researchers are legitimate researchers and not malicious computer users.

8. The method of claim 1, further comprising: providing a candidate researcher with access credentials for a test computer system; monitoring computer interactions of the candidate researcher with the test computer system; assessing skill levels of the candidate researcher based on the computer interactions; providing the candidate researcher with access credentials for the test computer system on results of assessing skill levels; and assessing the candidate researcher for reliability and competence in real time as the candidate researcher communicates with the particular target system.

9. The method of claim 1, further comprising storing an audit trail of URLs that the researcher computer sends to the particular target system.

10. The method of claim 1, further comprising assessing which portions of the particular target system have been accessed by the researcher computer and which portions have not.

11. The method of claim 1, further comprising storing URLs of dynamically generated pages that the particular target system generates in response to action by the researcher computer.

12. The method of claim 1, further comprising storing keystroke logs of the researcher computer while accessing the particular target system.

13. The method of claim 12, further comprising: providing a payload to the researcher; and directing the researcher to install the payload onto the target system following a successful exploitation of a vulnerability of the target system.

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14. The method of claim 13, wherein the payload includes logic to direct communications between the target and the researcher computer through control logic.

15. The method of claim 1, further comprising storing URLs of dynamically generated pages that the particular target system generates in response to action by the researcher computer.

16. A computer vulnerability discovery system comprising:

interfaces to a plurality of researcher computers; control logic logically interposed between a researcher computer of the plurality of researcher computers and one or more target systems, wherein the researcher computer is a computer operated by, or to be operated by, an invited researcher, wherein an invited researcher is a person or organization selected to participate in one or more computer vulnerability research projects directed to researching and/or identifying computer vulnerabilities of the one or more target systems comprising one or more network component and/or one or more computer component;

storage for access credentials for a management computer associated with the control logic to allow access by particular ones of the plurality of researcher computers; storage for data about an assignment of a particular computer vulnerability research project of the one or more computer vulnerability research projects to the researcher computer or to the invited researcher, wherein the particular computer vulnerability research project relates to a particular target system;

a monitor, coupled to the control logic, for monitoring networked data communications between the researcher computer and the particular target system, wherein the networked data communications include communications that are usable to identify a candidate vulnerability of the particular target system; and storage for data about a candidate vulnerability of the particular target system based on a report received from the invited researcher resulting from the invited researcher's use of the researcher computer to interact with the particular target system.

17. The computer vulnerability discovery system of claim 16, further comprising:

storage for validation data about the report of the candidate vulnerability of the particular target system, including data about attempted duplication of the candidate vulnerability after receiving the report; and an output for providing a message triggering one or more remediation operations on the particular target system based at least in part upon the report.

18. The computer vulnerability discovery system of claim 16, further comprising storage for an audit trail of URLs that the researcher computer sends to the particular target system.

19. The computer vulnerability discovery system of claim 16, further comprising a payload to be provided to the researcher for use of the researcher to install onto the target system following a successful exploitation of a vulnerability of the target system.

20. The computer vulnerability discovery system of claim 16, further comprising storage for URLs of dynamically generated pages that the particular target system generates in response to action by the researcher computer.

21. Non-transitory computer-readable media having stored thereon instructions executable by a processor able to read the non-transitory computer-readable media, the instructions comprising:



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program code for accessing a computer vulnerability research project management system;

program code for accessing a database of vulnerability projects, wherein each vulnerability project is associated with a target computer system;

program code for accessing a database of assigned researchers, wherein a record of a researcher includes access credentials assigned to the researcher and/or a network address used by the researcher to access the computer vulnerability research project management system;

program code for providing access credentials or location data for a computer or application that is associated with the target computer system that allows the researcher to interact with the target computer system of a particular vulnerability research project indirectly; and

program code for inspecting, logging and monitoring network communications to and from the researcher computer and to and from the target computer system.

22. The non-transitory computer-readable media of claim 21, wherein the program code for inspecting, logging and monitoring network communications comprises program code for monitoring the number of communications between the researcher and the target systems.

23. The non-transitory computer-readable media of claim 21, wherein the program code for inspecting, logging and

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monitoring network communications comprises program code for comparing researcher activity to expected researcher activity corresponding to subject matter of an assigned vulnerability research project.

5 24. The non-transitory computer-readable media of claim 21, wherein the program code for inspecting, logging and monitoring network communications comprises program code for monitoring whether the researcher is attempting to access resources of the target computer system for which access is prohibited or out of scope for the particular vulnerability research project.

10 25. The non-transitory computer-readable media of claim 21, wherein the program code for inspecting, logging and monitoring network communications comprises program code for monitoring whether the researcher appears competent and/or diligent.

15 26. The non-transitory computer-readable media of claim 21, wherein the program code for inspecting, logging and monitoring network communications comprises program code for storing an audit trail of URLs that the researcher sends to the target computer system, keystrokes of the researcher to the target computer system, and URLs of dynamically generated pages that the target computer system generates in response to action by the researcher.

\* \* \* \* \*